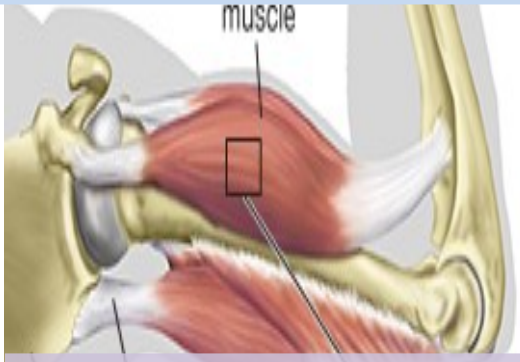
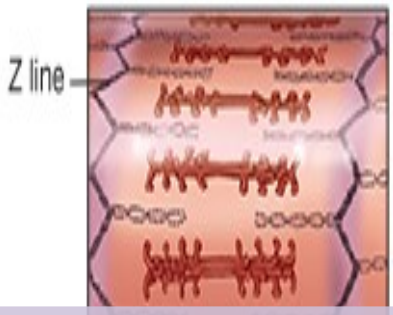
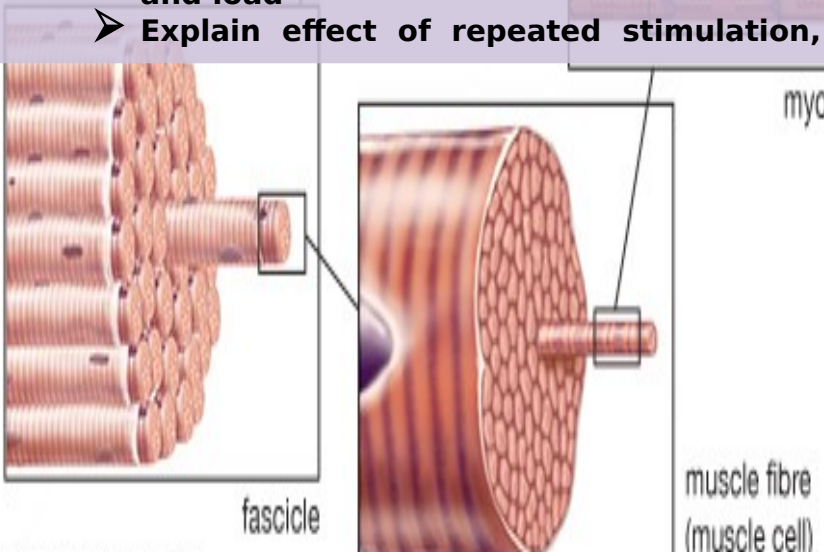
Factors affecting skeletal muscle contraction





Objectives

- Differentiate between isotonic and isometric contraction
- Explain effect of muscle fiber type on simple muscle twitch and compare white versus red muscle
- Explain effect of Muscle fiber length (Pre-load) on simple muscle twitch Interpret scenarios on length-tension curves (passive and active tension)
- Explain the bell shaped active tension curve
- Explain effect of afterload on simple muscle twitch and use knowledge of relationship between velocity and load
- Explain effect of repeated stimulation, Fatigue and



Types of muscle contraction

- Skeletal muscle has 2 elements:

A- Contractile element B- Elastic element

-Muscle contraction means shortening of the contractile element.

- If contractile element shortening is associated with a **decrease** in the whole muscle **length** it is called **isotonic contraction**.

- If contractile element shortening is associated with lengthening of muscle elastic elements with whole muscle **length constant** it is called **isometric contraction**.

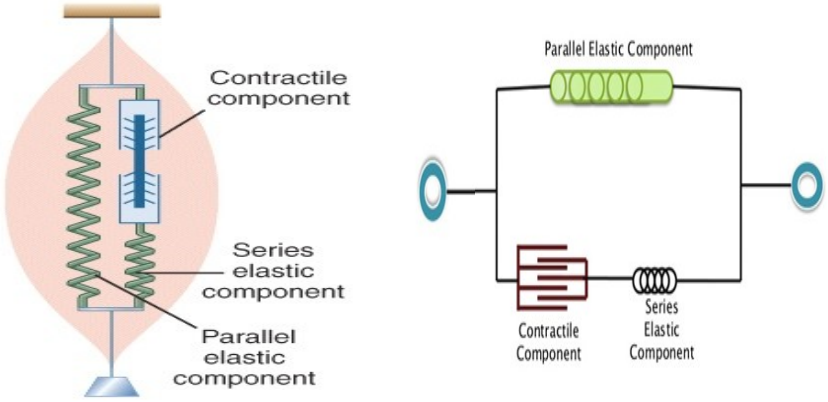


Fig (1): Skeletal muscle contractile and elastic elements.

Isometric contraction

- Active tension developed by shortening of contractile elements is less than load.
- Contractile element shortening
- Lengthening of elastic elements
- Whole muscle length is not changed=isometric
- Load is not lifted=External work is zero

Isotonic contraction

- Tension developed by shortening of contractile elements enough to carry the load
- Contractile element shortening
- Whole muscle length is shortened
- Load is lifted=External work
- The tension remains constant (= isotonic) and is followed by shortening.

➢ Compare between isometric and isotonic contraction

	Isometric contraction	Isotonic contraction
Muscle length	not changed	shortened
Contractile element	Contraction and shortening	Contraction and shortening
Elastic element	lengthening	shortening
Tension developed	Less than load	Enough to carry the load, constant tension
Load lifting	Not lifted	lifted
External work, mechanical efficiency	zero	External work

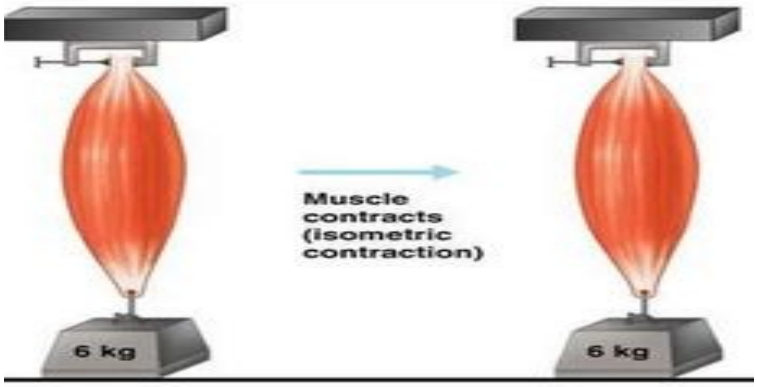


Fig (2a): Skeletal muscle isometric contraction

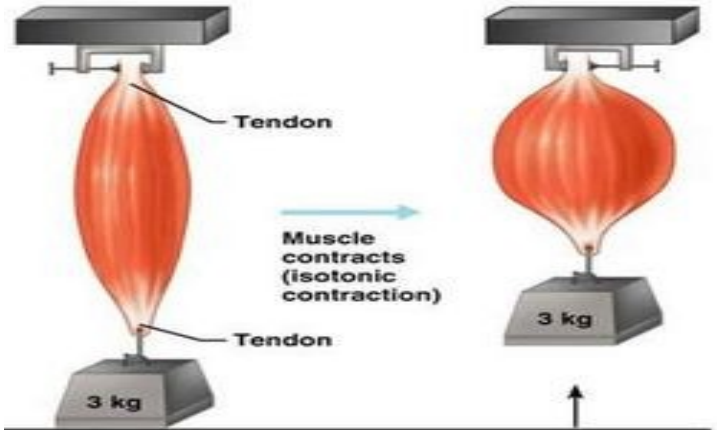


Fig (2b): Skeletal muscle isotonic contraction

Factors affecting skeletal muscle contraction

Muscle responds to a single action potential by a simple muscle twitch (SMT).

This mechanical response **can be affected by**:

1. Type of the muscle fiber
2. Initial length of the muscle fiber (pre-load)
3. Afterload
4. Successive stimulation
5. Fatigue
6. Temperature

1-Effect of muscle fiber type on SMT

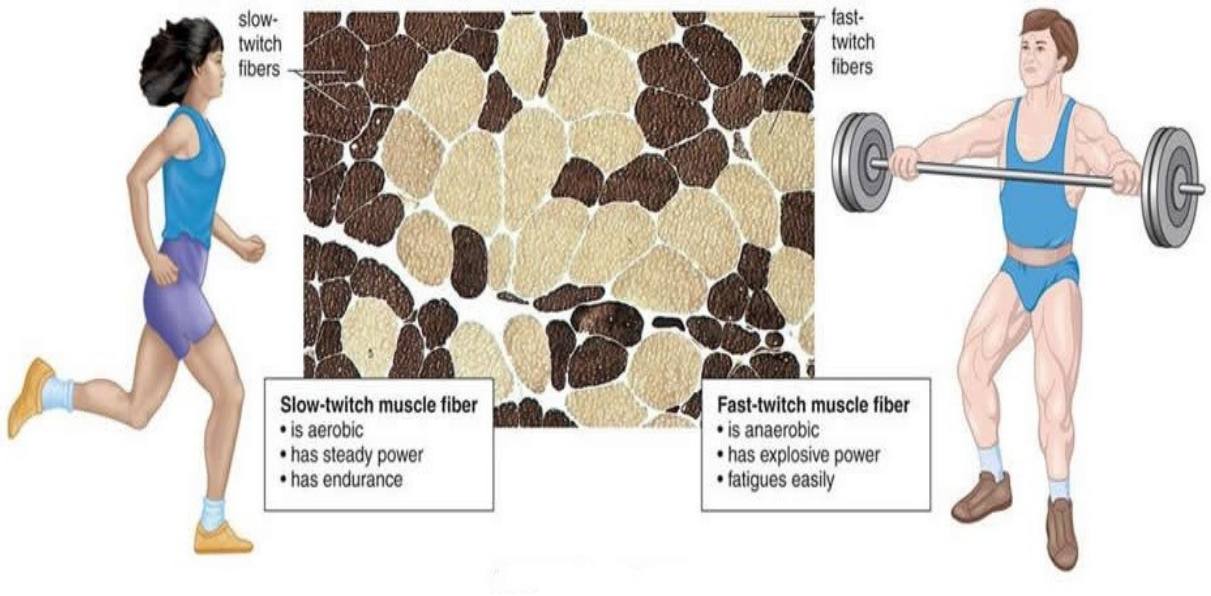


Fig (3): Different types of exercise use different muscle types.

	Slow oxidative red muscle fibers Type I	**Fast glycolytic white muscle fibers Type II b**
Latent period	Long	Short
Contraction speed	Slow myosin ATPase, slow cross bridge cycle, slow speed of contraction	High myosin ATPase, fast cross bridge, fast contraction
Duration twitch	Up to 100 msec	As short as 7.5 msec
Exercise type	High endurance, low intensity prolonged aerobic exercise as Swimming- marathon	Low endurance, high intensity exercise that need power, speed for short duration as lifting weight or 100 m sprint

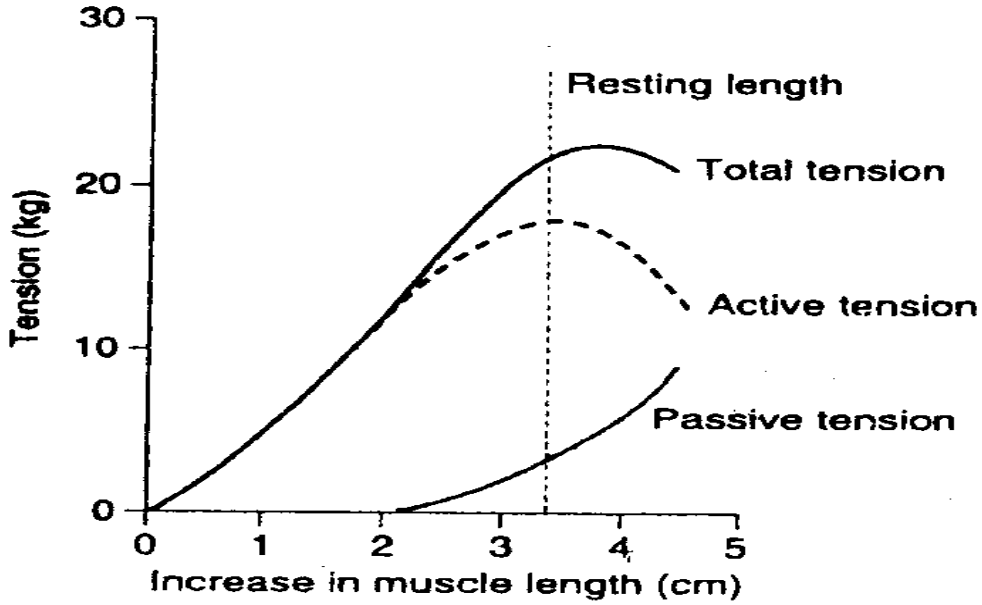
2-Effect of muscle fiber length on SMT

Pre-load effect:

- Stretching un-stimulated muscle will stretch the muscle elastic elements producing **passive tension**.
- **As stretch increases, passive tension increases**.
- When the muscle is stimulated to **contract "iso-metrically**" at **different increasing lengths** , the recorded ***total tension*** is the summation of both:

- **Passive** tension caused by **elastic elements** stretch.
- **Active** tension caused by **contractile elements contraction**.

The Total tension curve rises to maximum and then declines



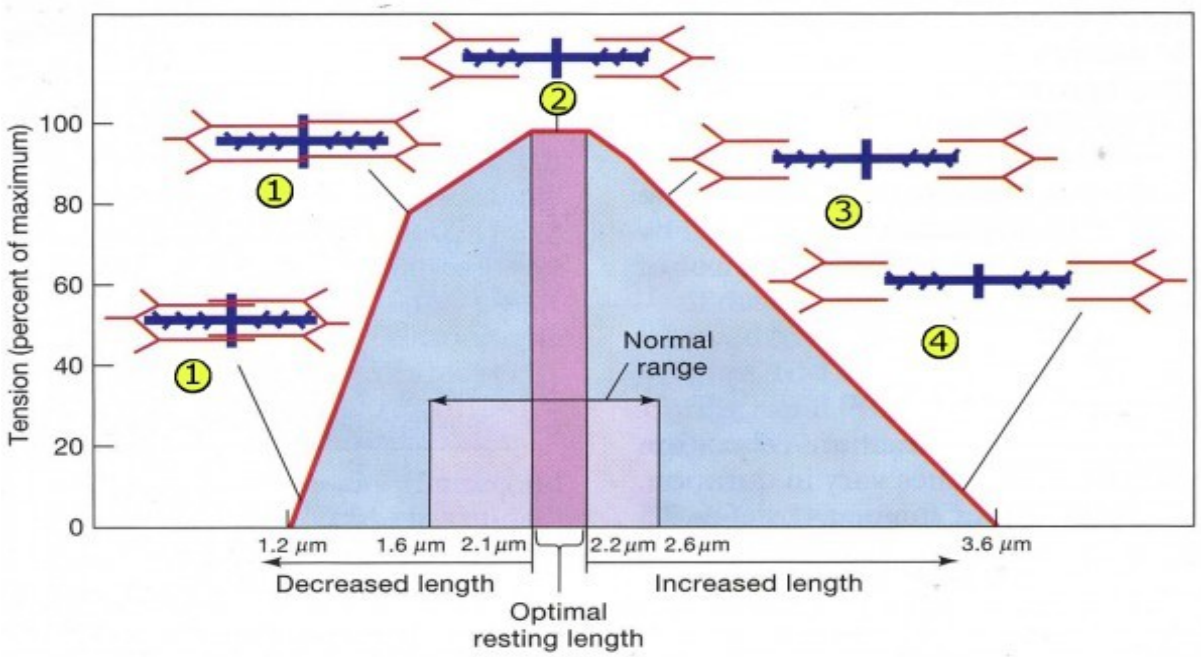
- Fig (4): Effect of stretch on muscle total, passive and active tension

Describe length-tension relationship:

- It is the effect of **stretch or pre-load** on muscle **active** tension.

➢ According to **starling law**:

- The **strength** of muscle contraction is **directly proportionate** to the initial **length** of the muscle **within physiological limit**.



- Fig (5): Length-tension relationship (Starling law)

- ***Effect of length change on muscle active tension***

Length	**short initial length**	**Increasing muscle length**	**Optimal length**	**Above the optimal length**
Sarcomere length	short	Increase	Optimal length **(2 - 2.2 µm)**	Actin filaments are pulled away from myosin heads
Actin-myosin interaction	Actin filaments will be crowded at the center of sarcomere	Better interaction	Maximum interaction	decrease
Cross bridge cycle	Decrease	Increase	maximum	decrease
Active Tension	decreases	Increasing	maximum	decrease

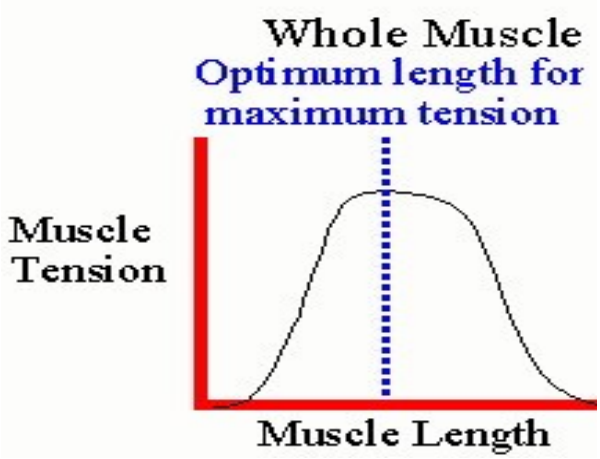


Fig (6): Skeletal muscle resting length

- **Muscle resting length:**
- It is the length of the muscle at which the active tension is maximal, sarcomere length is optimum (2 - 2.2 µm).
- Normally, our muscles are attached in the body at or near their resting length when they start to contract.

3-Effect of after-load on skeletal muscle contraction

Force-velocity relationship:

- The velocity of muscle contraction varies inversely with the afterload, which is the load against which the muscle exerts its contractile force.

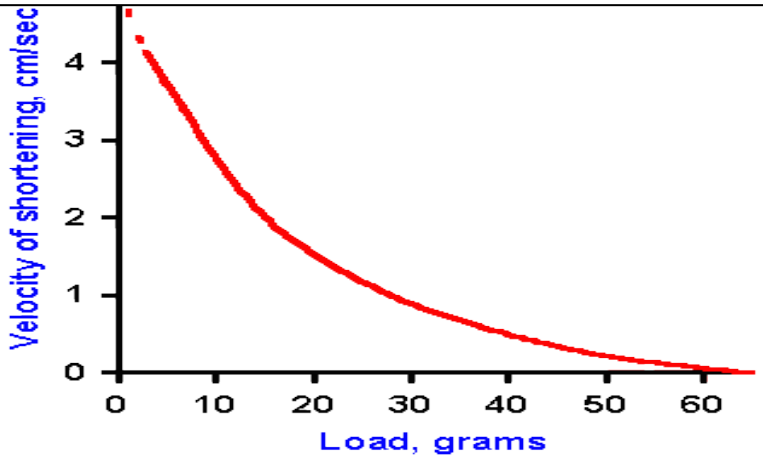


Fig (7): Force- velocity relationship

- Velocity of shortening during iso-tonic contraction (Rate of cross bridge cycle) is inversely related to the after-load
- Zero load= maximum velocity (V Max)

- Maximum load= zero velocity= iso-metric contraction

4- Effect of successive (repeated) stimulation:

- Contraction period in skeletal muscle starts after the end of (ARP)
- Successive stimulation leads to contraction summation
- If the second stimulus falls in the contraction phase of the previous twitch this leads to tetanus
- Tetanus is continuous muscle contraction without relaxation.

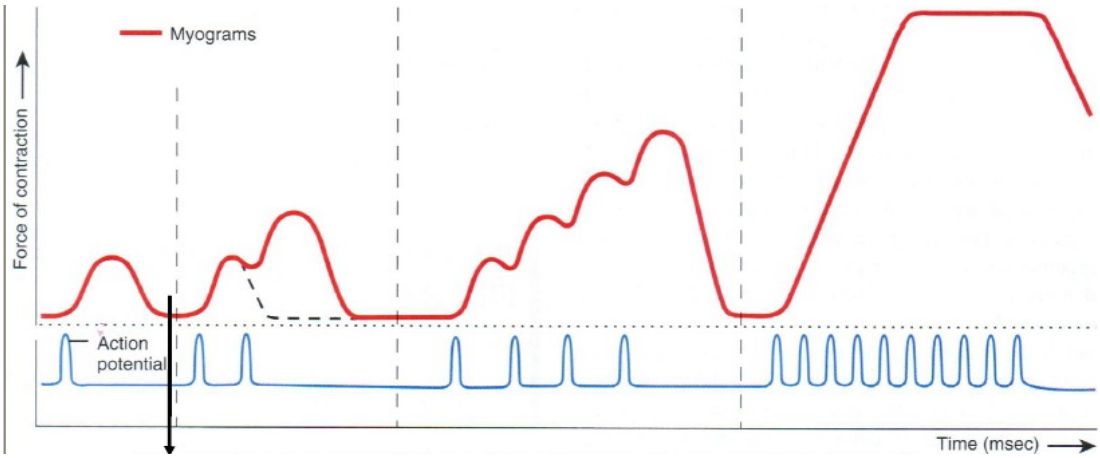


Fig (8): Contraction summation

Force-frequency relation ship:=Treppe (= staircase) phenomenon:

- It is an increase in the tension developed during each successive twitch, then after several contractions, a uniform tension per contraction is reached

  - ***Why?***

- Due to increased calcium availability, calcium accumulation because the rate of calcium release is more than its uptake by the sarcoplasmic reticulum

5- Effect of fatigue

Decrease in the amplitude and longer duration of SMT
Repeated stimulation leads to depletion of neurotransmitters at neuromuscular junction and fatigue.

6- Effect of temperature:

Skeletal muscle **warming** produces **short duration** and **higher amplitude** muscle twitch.
Skeletal muscle **cooling** produces **long duration** and **lower amplitude** muscle twitch.